

The transition from the sub-tropics to the tropics: an intercomparison study

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Special thanks to A. Gettelman (NCAR) and M. Webb (UKMO).
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Cloud-Climate feedbacks

WCRP 1998:

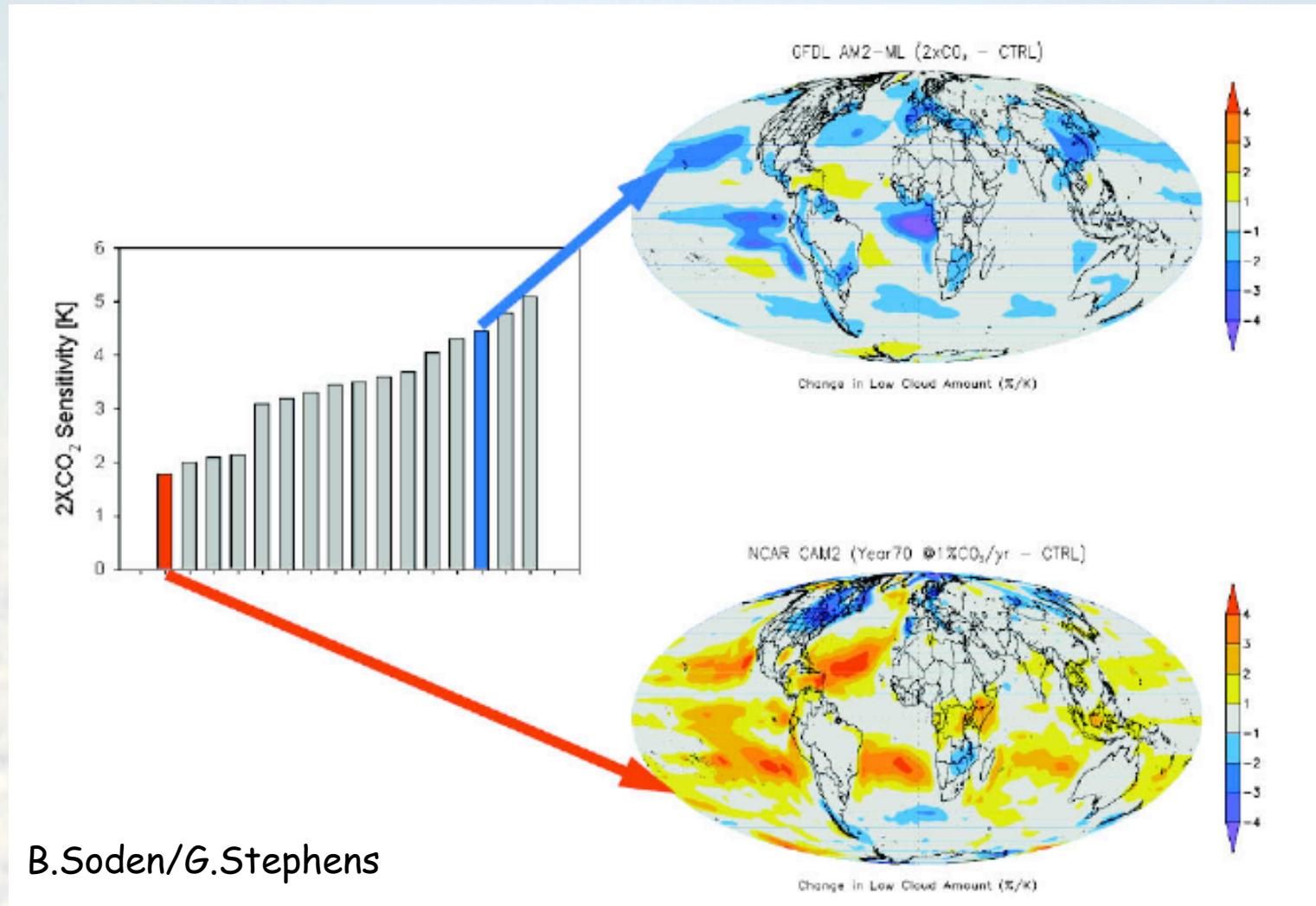
"Reducing the uncertainty in cloud-climate feedbacks is one of the toughest challenges facing the climate community"

IPCC 2007:

- "Water vapor changes represent the largest feedback affecting climate sensitivity and are now better understood"
- "Cloud feedbacks remain the largest source of uncertainty"

But which clouds and where and why?

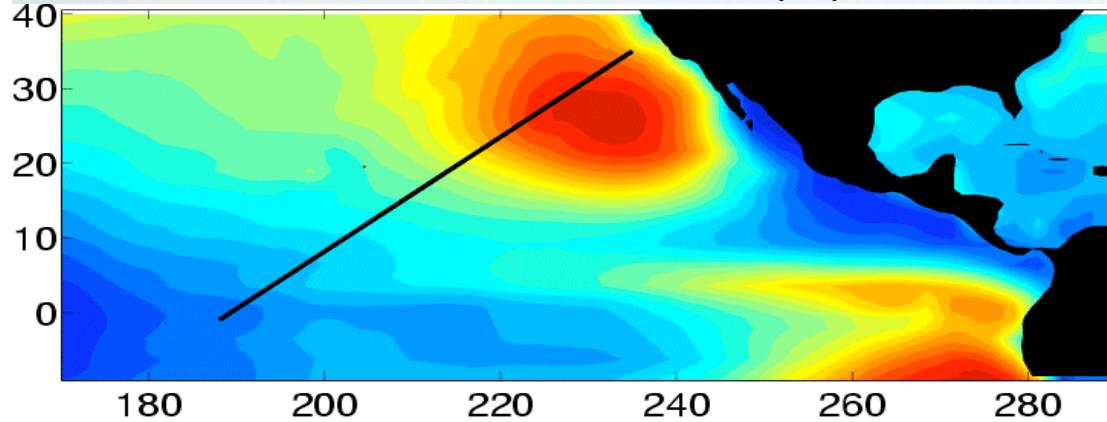
GFDL and NCAR have opposite low cloud cover sensitivity to CO₂ doubling



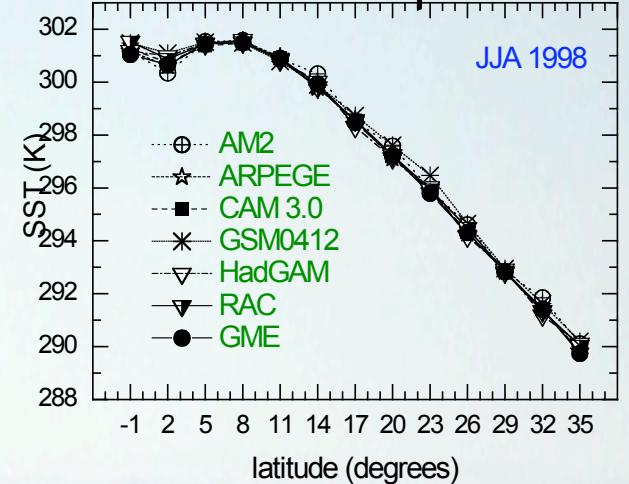
Large sensitivity in the sub-tropics

GCSS/WGNE Pacific Cross-section Intercomparison (GPCI)

ISCCP Low Cloud Cover (%)



Sea Surface Temperature



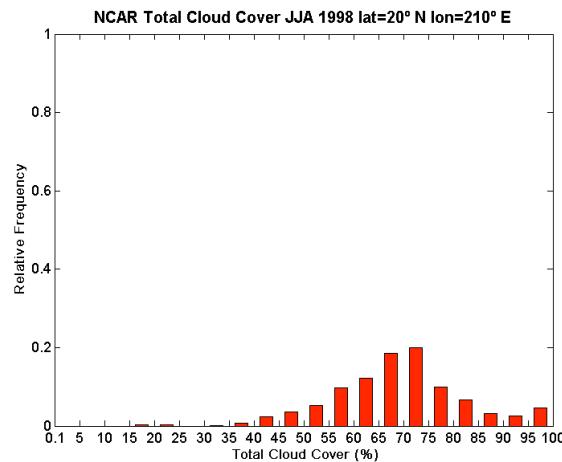
GPCI is a working group of the GEWEX Cloud System Study (GCSS)
- funded by the NASA MAP Program

Models and observations are analyzed along a Pacific Ocean cross-section from the stratocumulus regions, across the shallow cumulus areas, to the deep convection regions

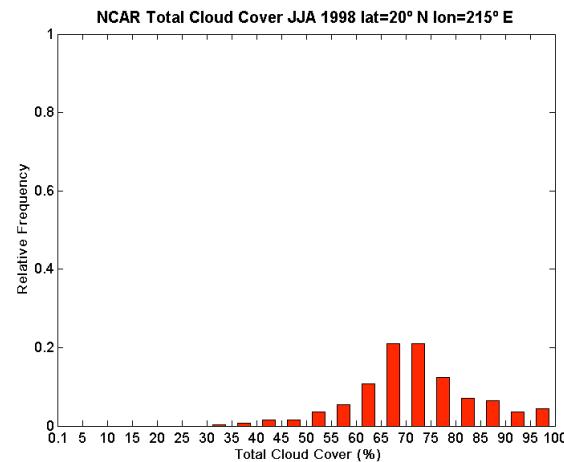
Models: GFDL, NCAR, UKMO, JMA, MF, KNMI, DWD, NCEP, MPI, ECMWF, BMRC, NASA/GISS, UCSD, UQM, LMD, CMC, CSU, GKSS

How representative is the cross-section? Total cloud cover histograms

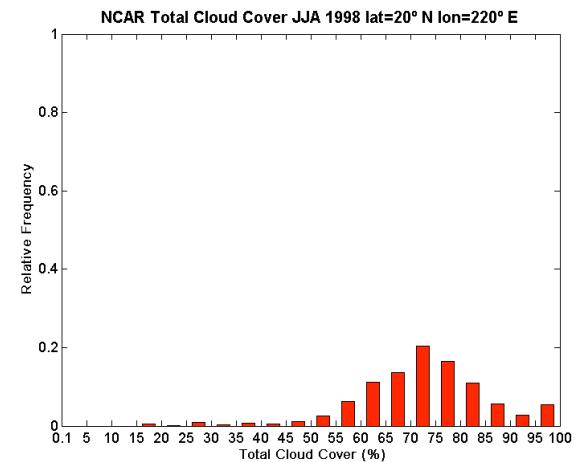
20 N, 210 E



NCAR, 20 N, 215 E

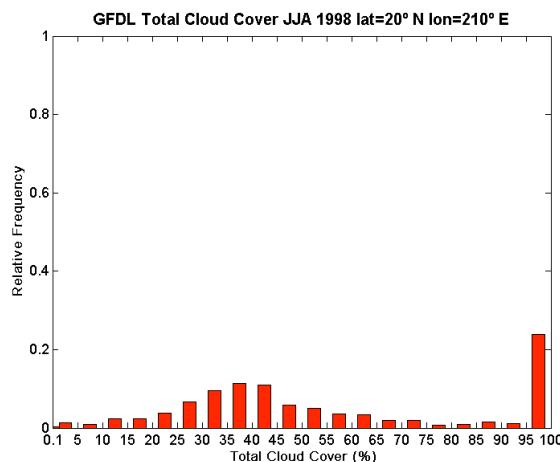


20 N, 220 E

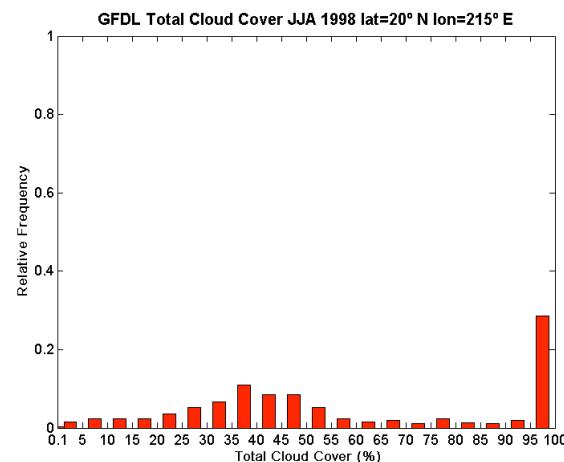


Results from adjacent points are similar. Models are different.

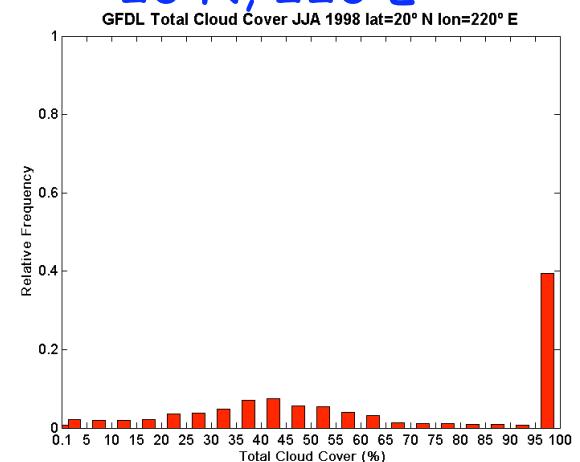
20 N, 210 E



GFDL, 20 N, 215 E

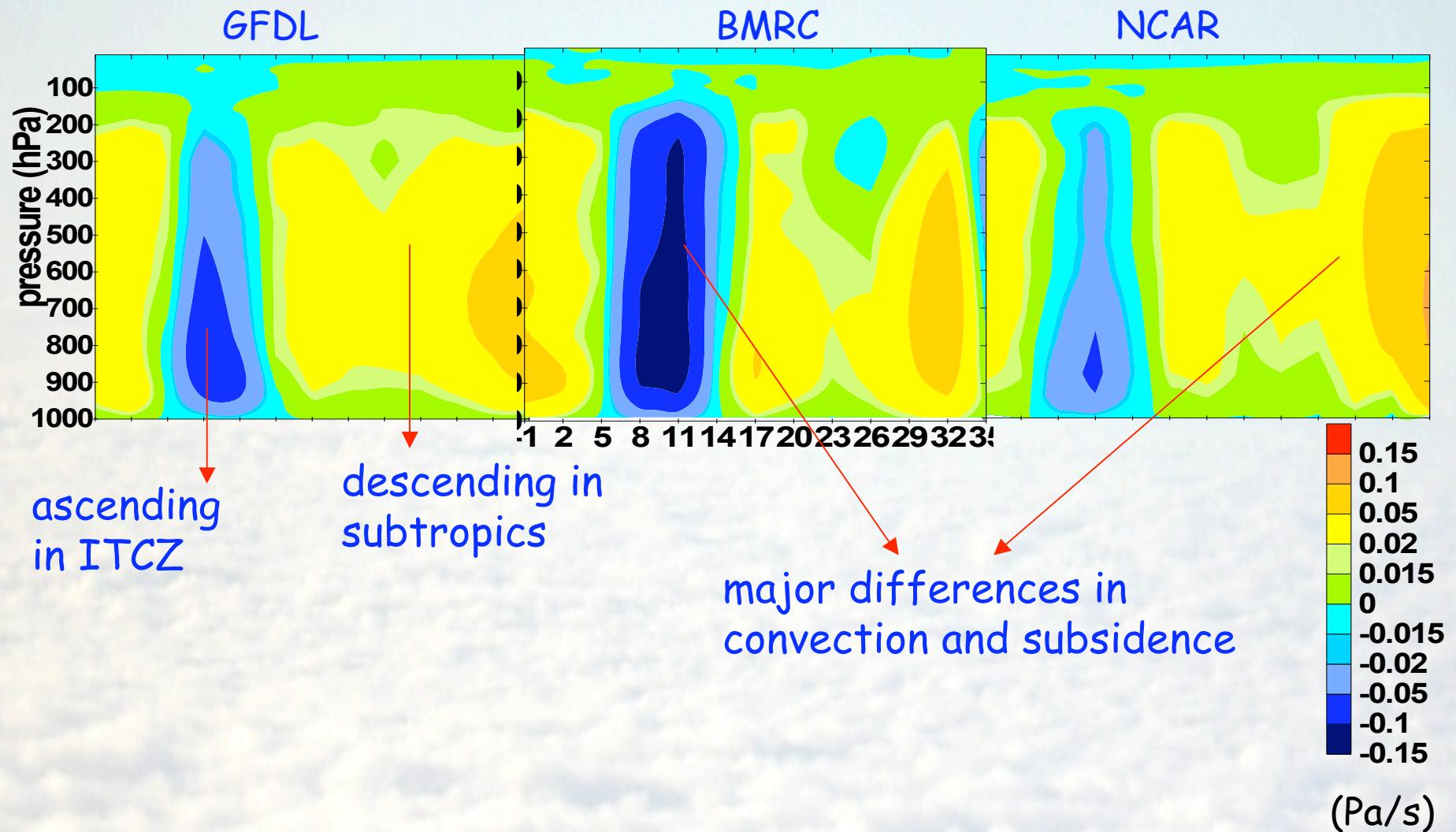


20 N, 220 E

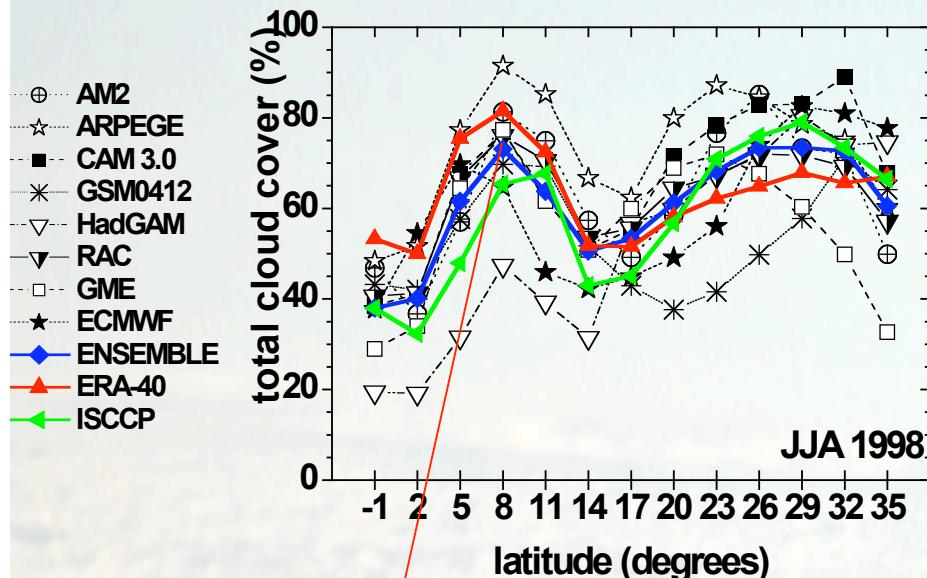


GPCI: JJA98 mean vertical velocity

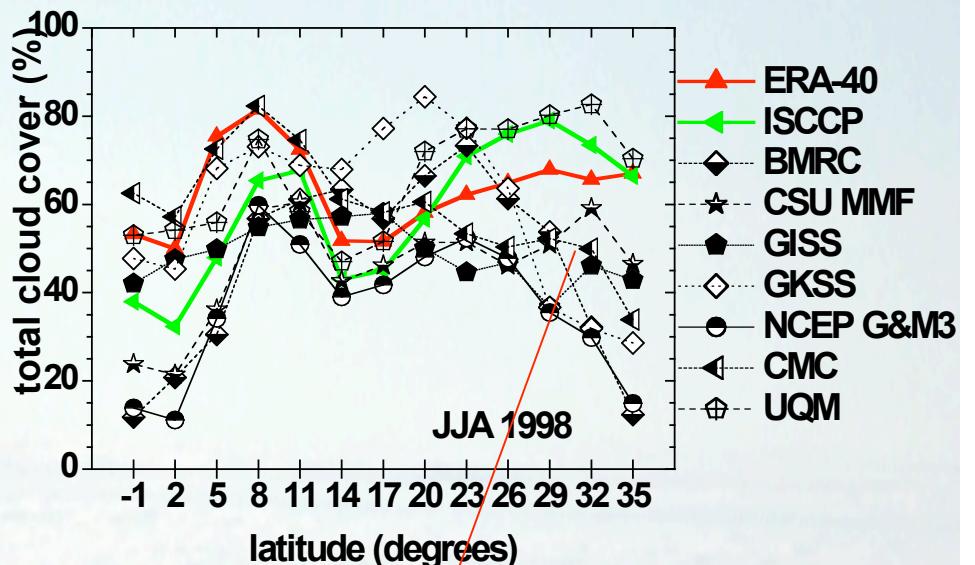
All models exhibit Hadley-circulation-like features...



Total Cloud Cover (JJA98)

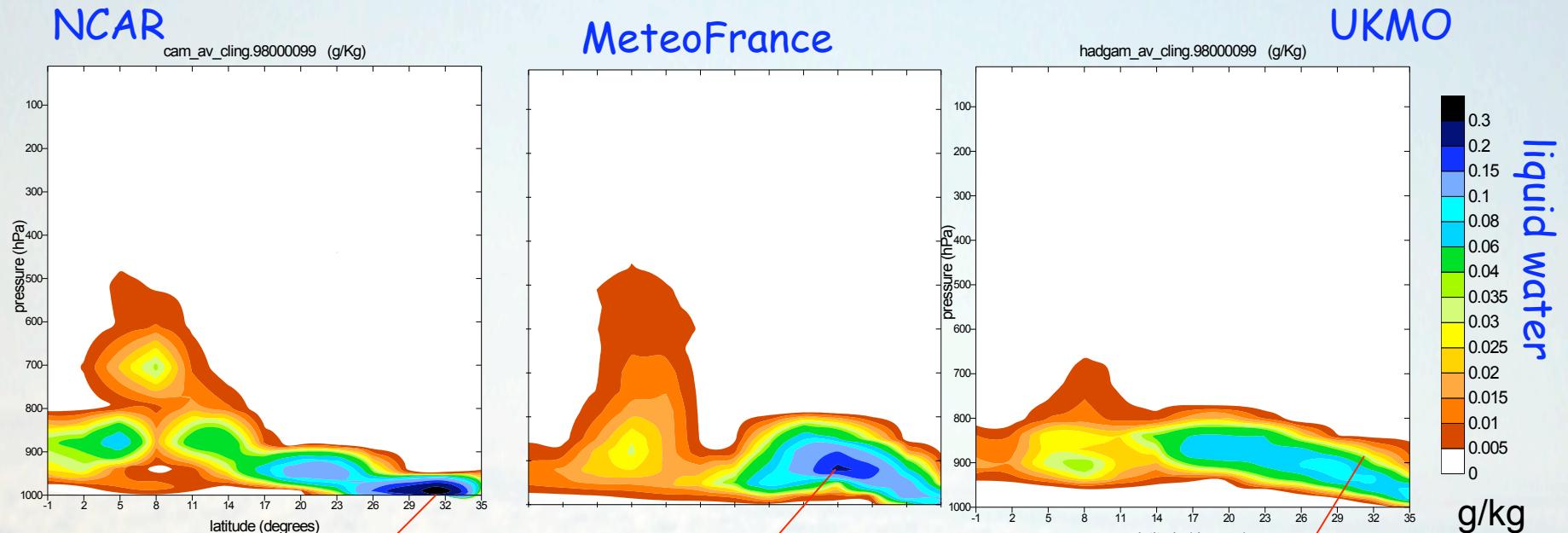


Overestimation
of
deep/shallow
convective cloud cover



Underestimation
of stratocumulus
cloud cover

Mean GPCI liquid water crossection - JJA98

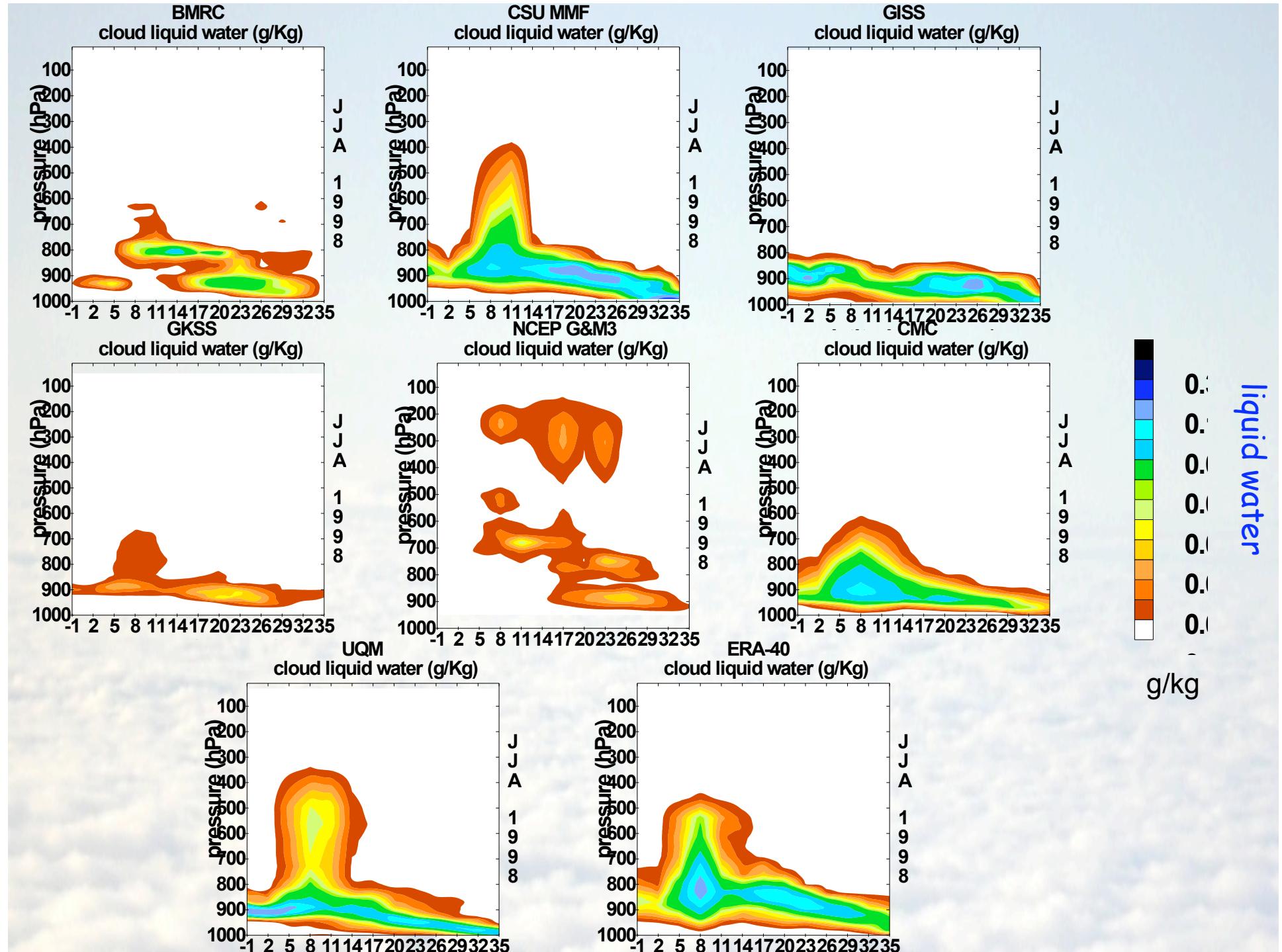


Too shallow -> fog

Is this too much
liquid water?

How deep should
the PBL be..?

There is a need for observations of cloud and boundary layer (PBL) parameters: PBL height, liquid water,...



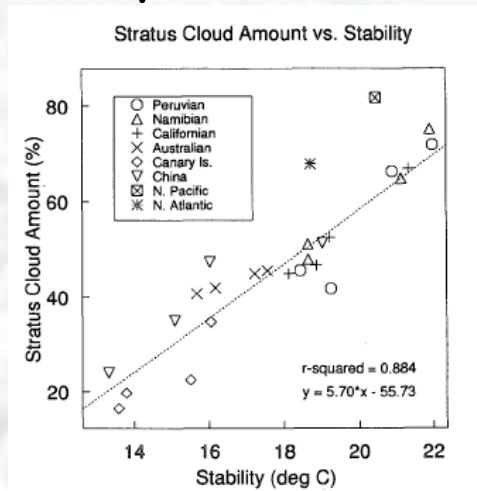
But ... this is a surface/boundary-layer/free-troposphere coupled problem

Boundary layer height function of subsidence + entrainment:

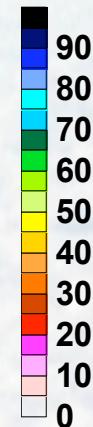
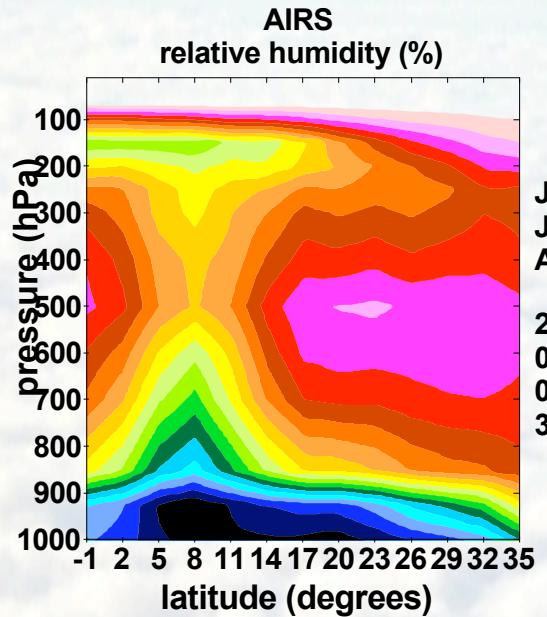
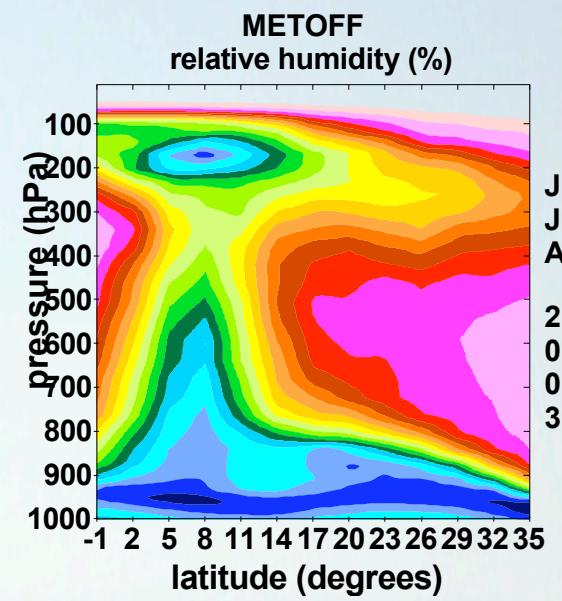
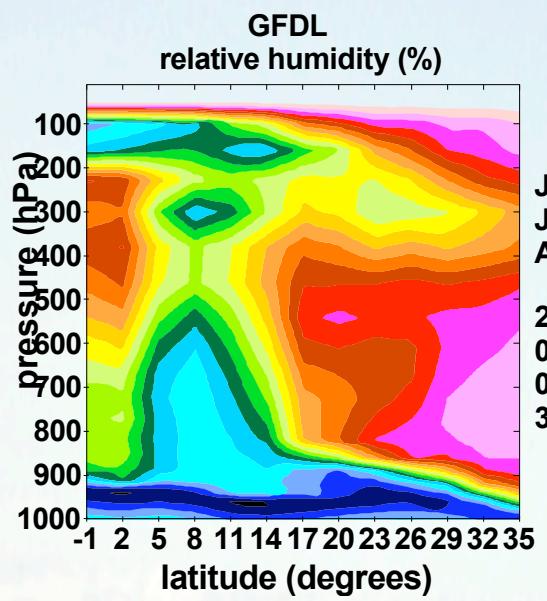
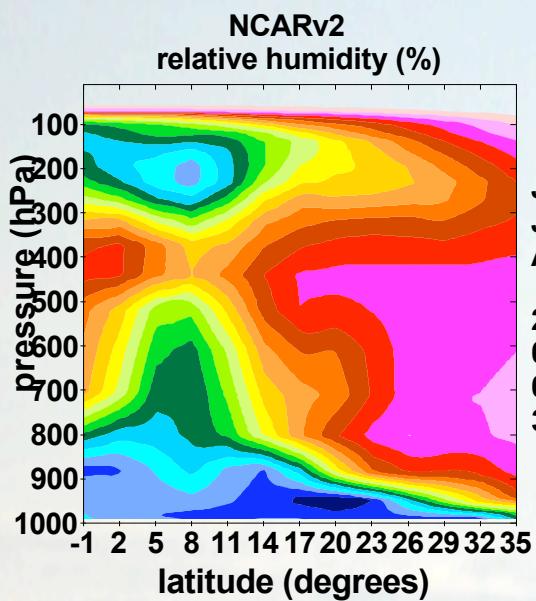
$$\frac{dh}{dt} = w_{LS} + w_{PBL}$$

Cloud cover is function of PBL height: deeper PBL=> less cloud

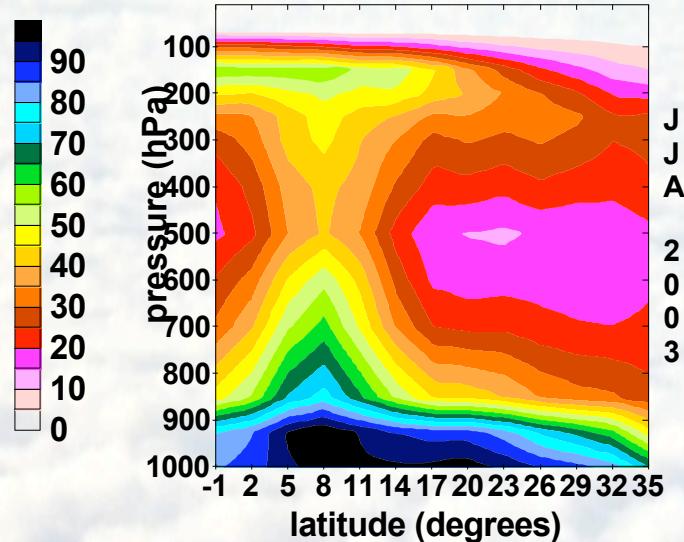
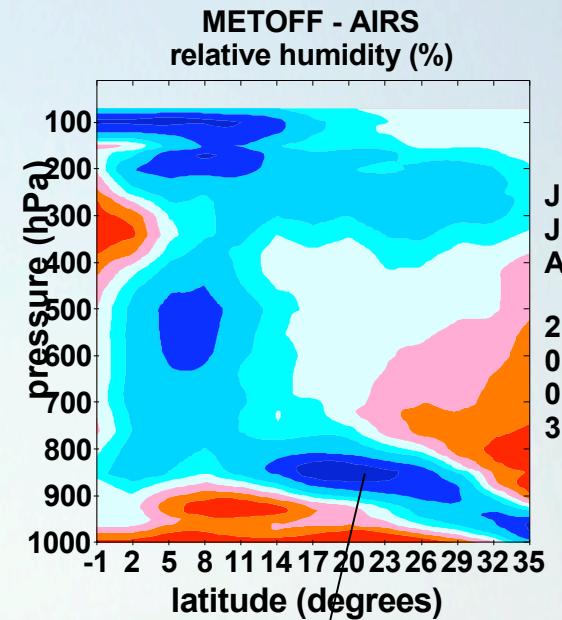
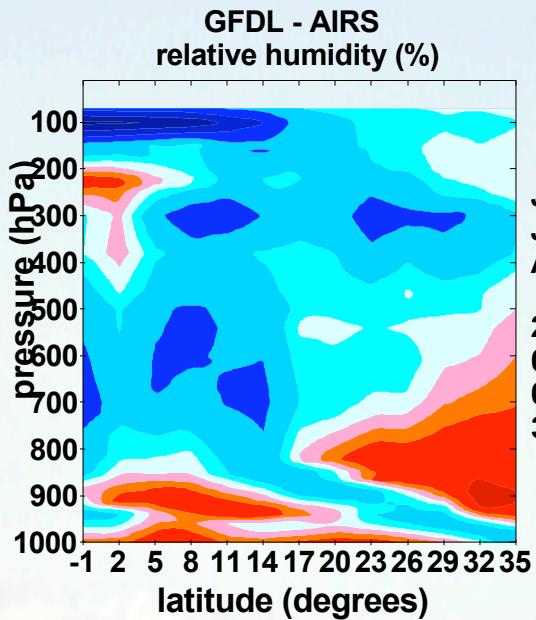
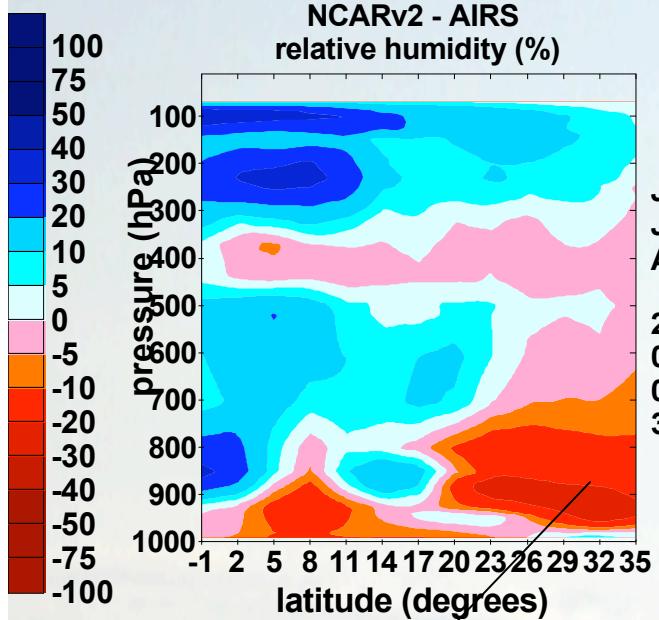
Low cloud cover is function (empirical) of stability = $\theta_{700} - SST$



GPCI mean relative humidity - JJA 2003



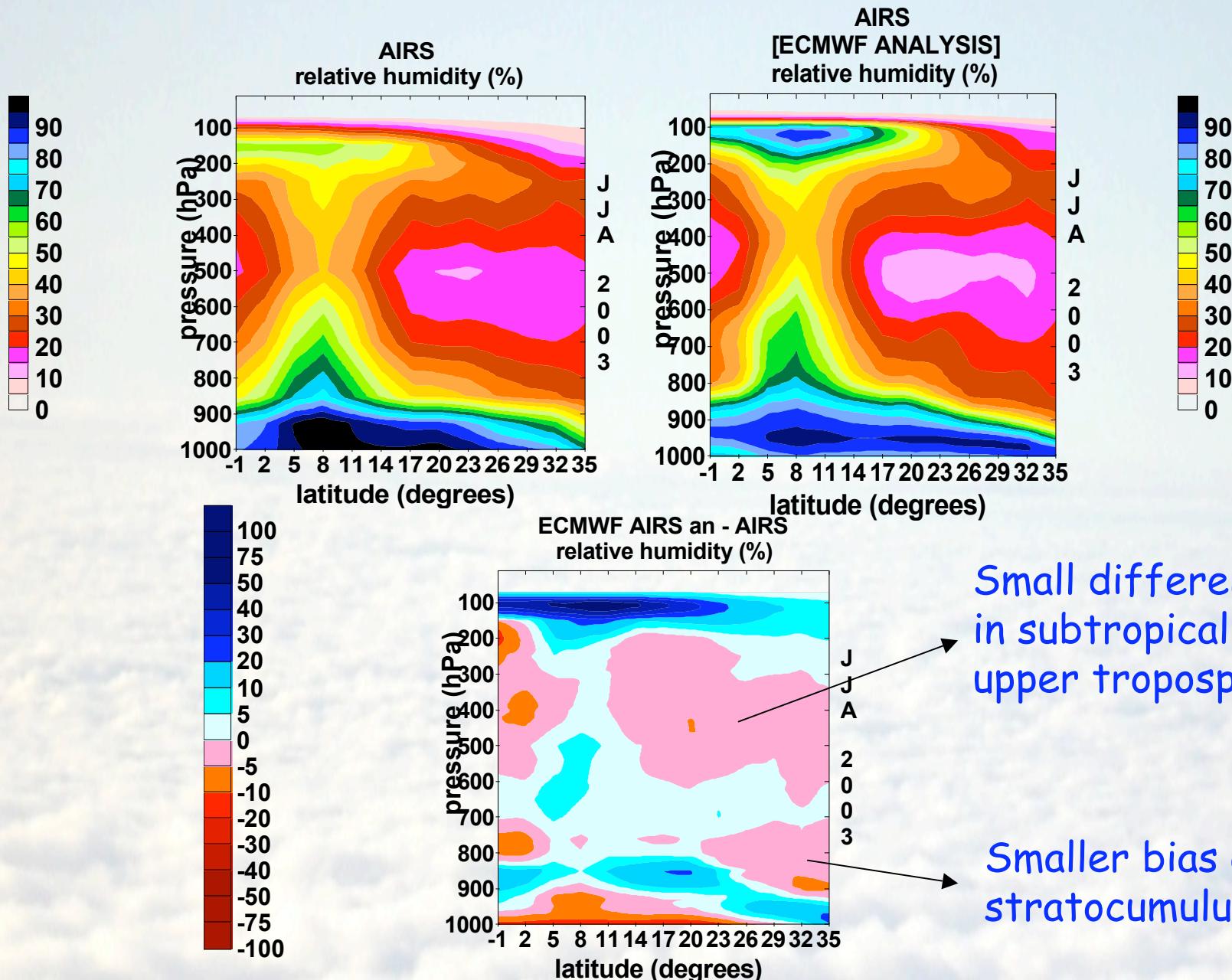
Relative humidity differences: model- AIRS (JJA03)



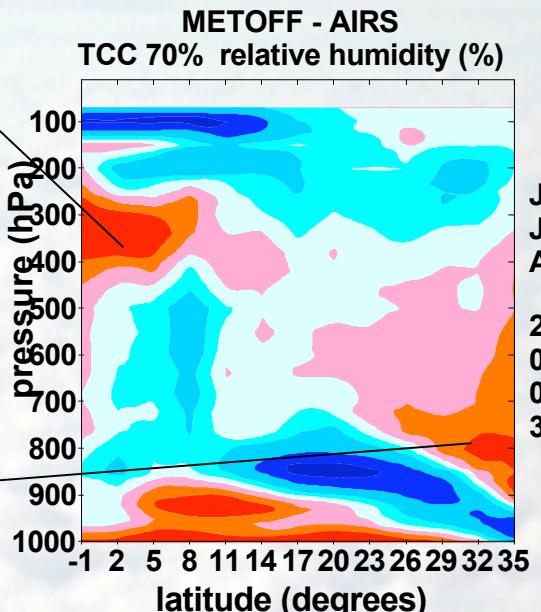
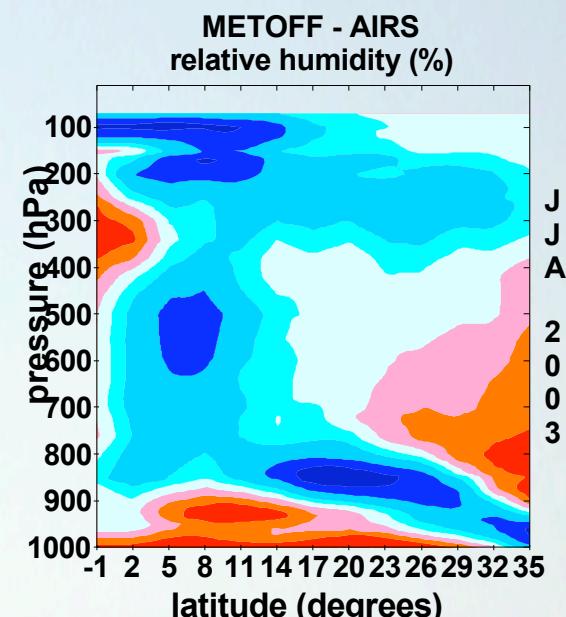
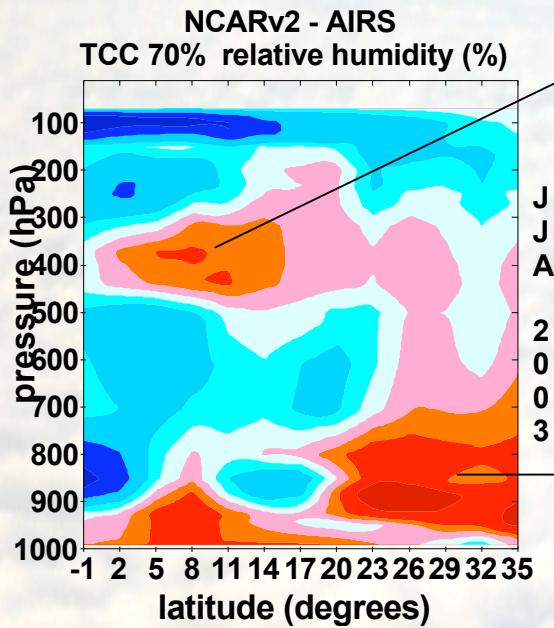
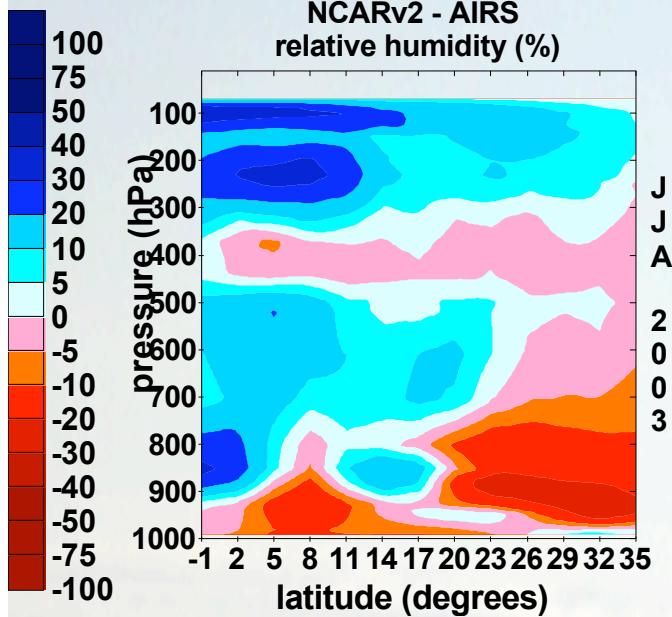
Models are
much drier
above Sc: AIRS
sampling ...?

UKMO PBL is
deeper and/or
moister/colder

Rel. humidity: AIRS and ECMWF analysis (with AIRS)



Model RH only for TCC < 70%: model- AIRS (JJA03)

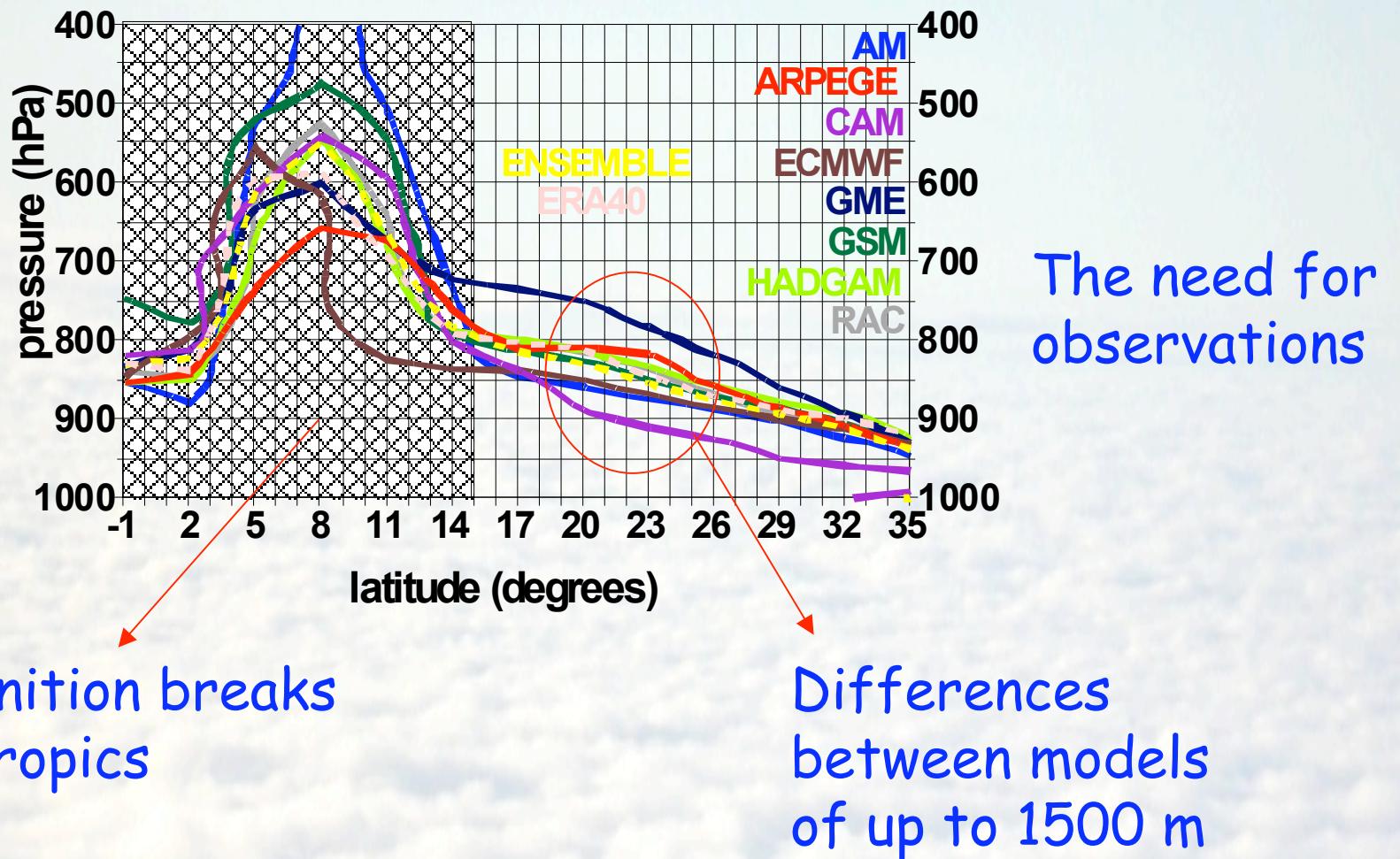


Larger bias in
tropical upper
troposphere

Slightly smaller
bias above Sc

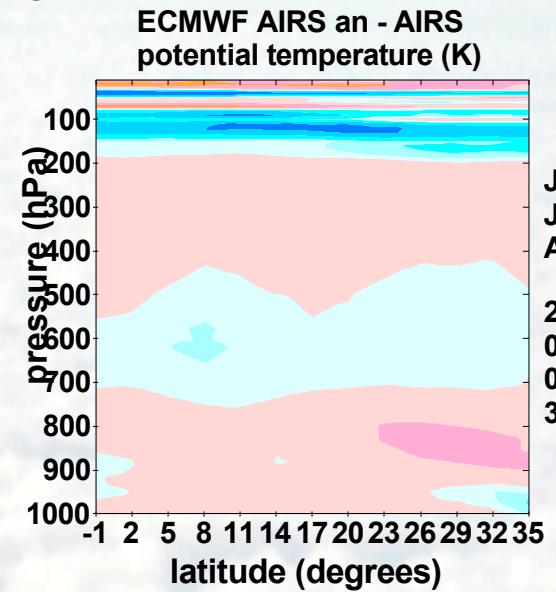
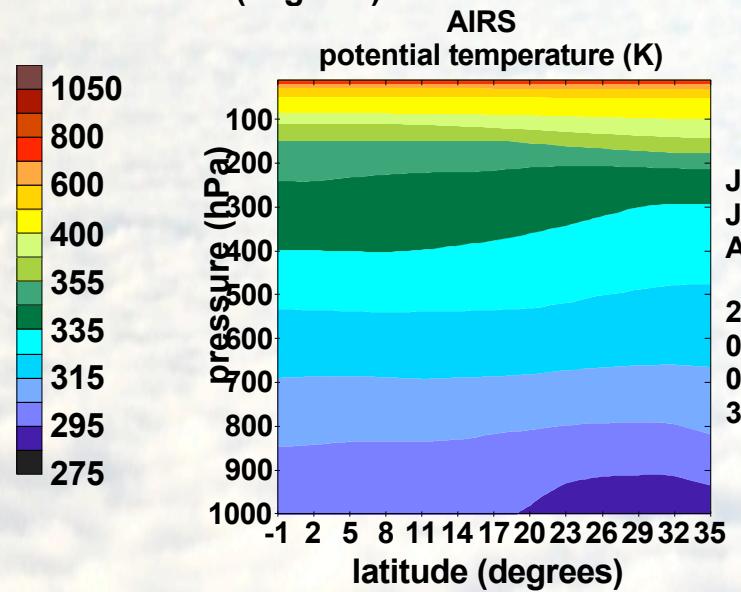
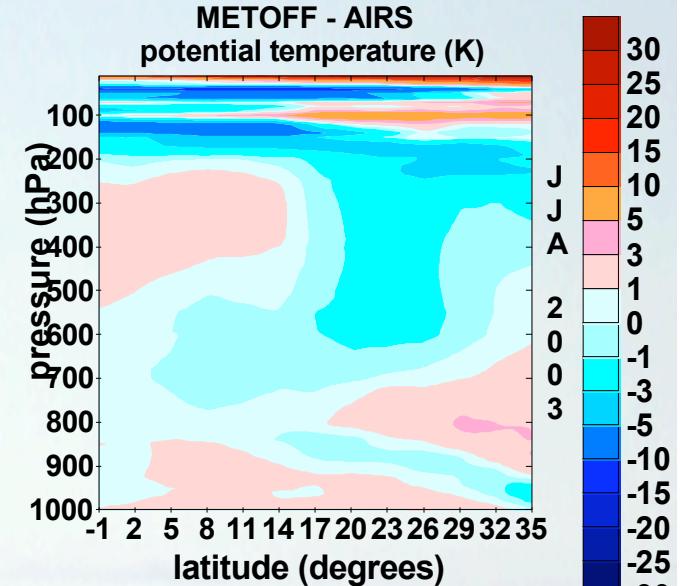
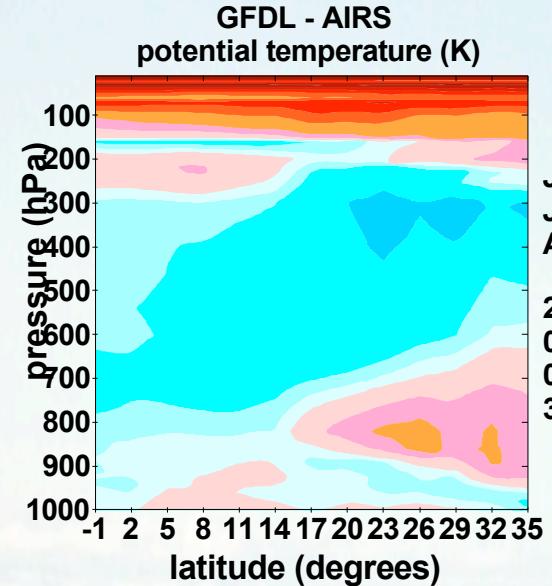
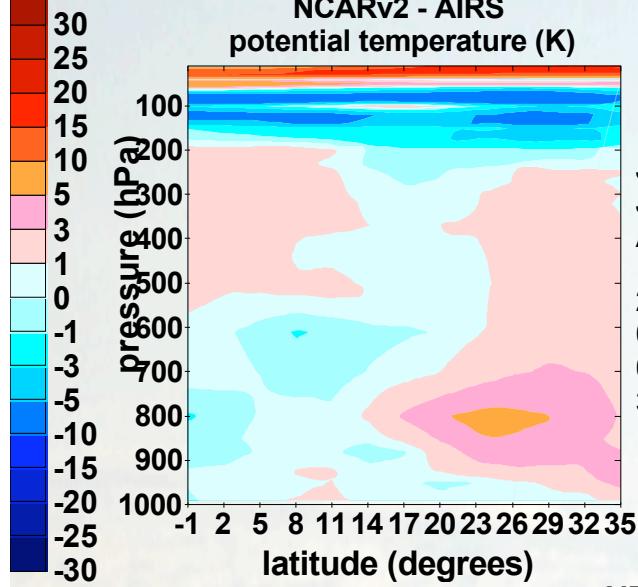
GPCI - Boundary layer height

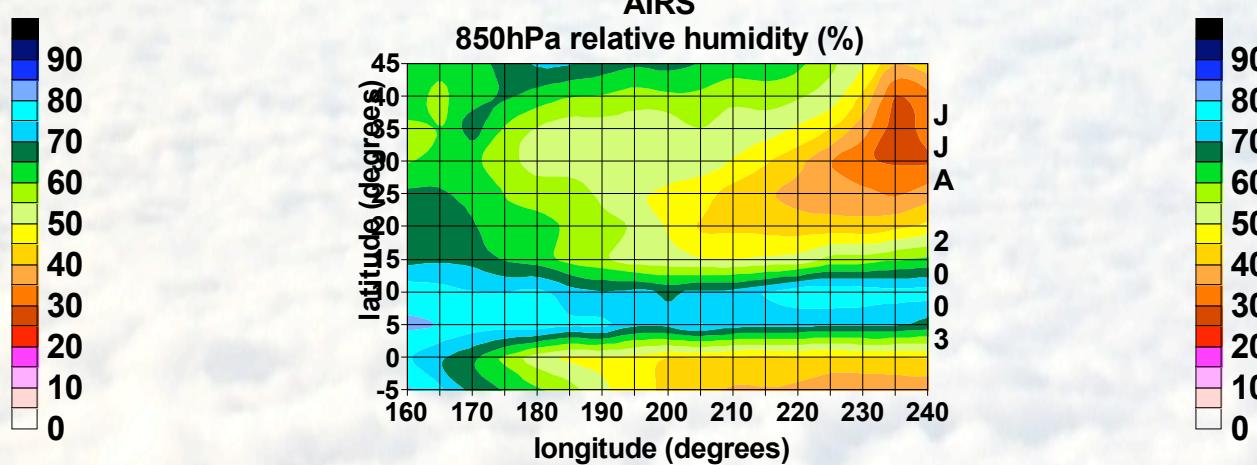
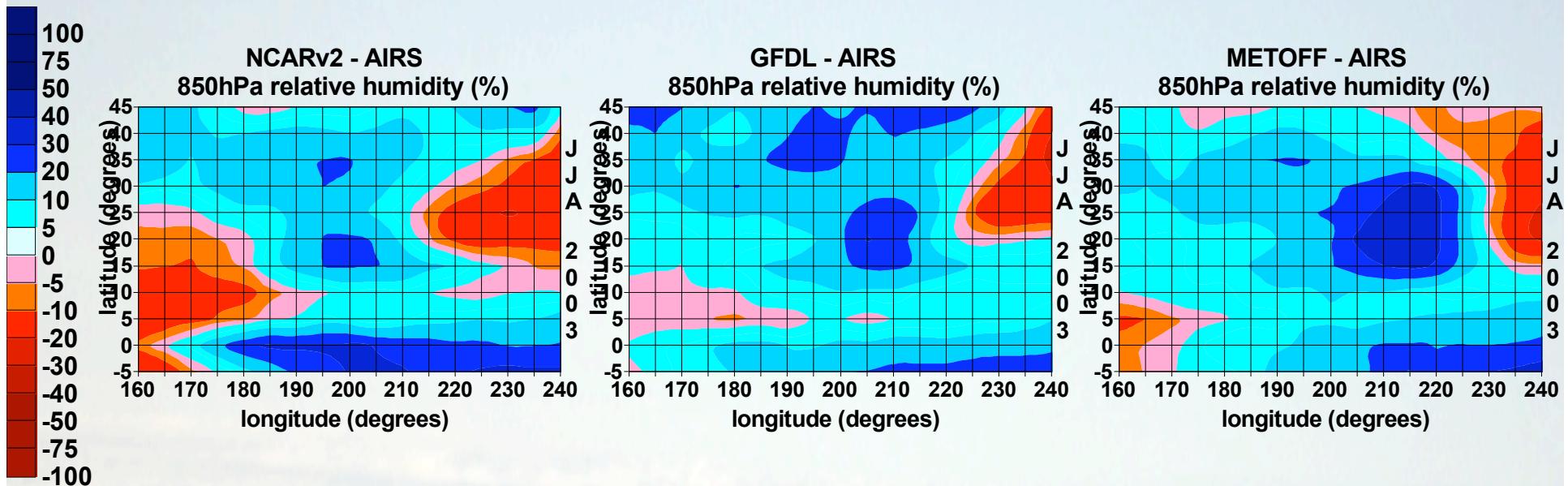
Boundary layer height defined as RH=50% isoline



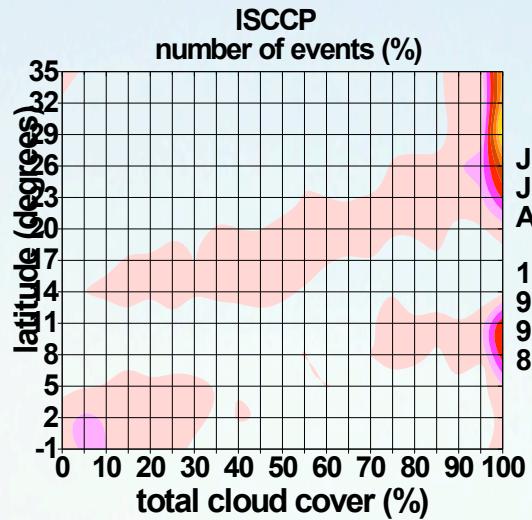
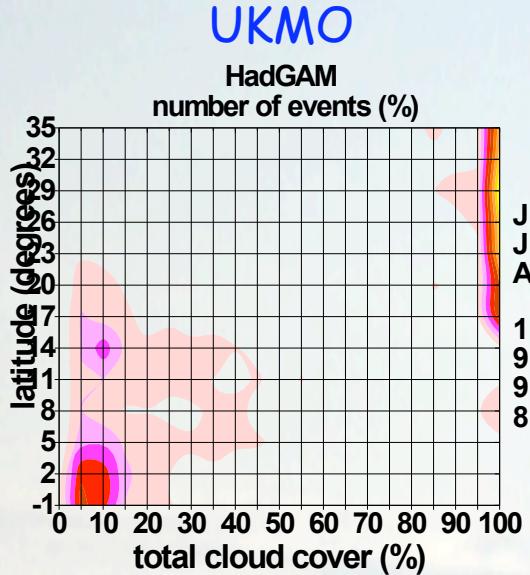
Summary

- Cloud feedbacks remain the largest source of uncertainty in climate prediction
- Largest sensitivity in sub-tropical boundary layer clouds ... where parameterizations have serious problems
- This is a surface/boundary-layer/free-troposphere coupled problem
- GCSS Pacific Cross-section Intercomparison (GPCI) allows for in-depth study of tropics and sub-tropics
- AIRS is fundamental for GPCI model evaluation and may provide useful boundary layer height information

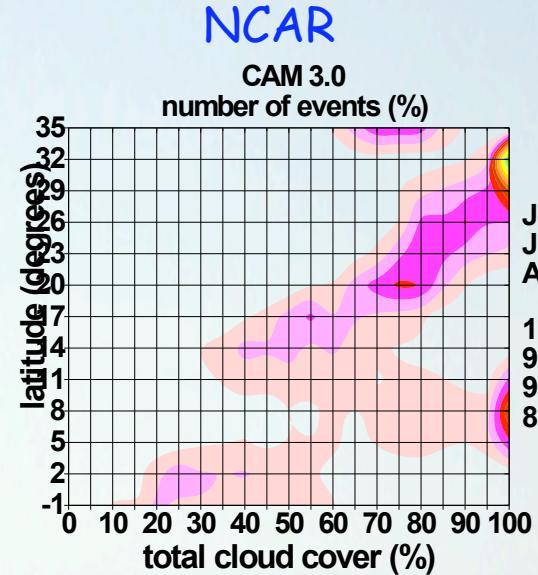




Histograms of TCC: ISCCP versus models



ISCCP is between
continuous and bimodal



- NCAR low cloud parameterization is based on climatology => continuous transition
- UKMO (and partly GFDL) cloudy-PBL parameterizations are based on the idea of distinct-regimes => discontinuous transition
- ISCCP suggests that none of these two "extreme" concepts is fully valid => relevant for parameterization development